

TITLE

DRIVE TRAIN MEMBER HAVING CONVEX SPLINES

BACKGROUND OF THE INVENTION

This invention relates in general to vehicle drive train assemblies for transferring rotational power, such as from an engine to an axle assembly of the vehicle. In particular, this invention relates to a drive train member such as a driveshaft having convex splines.

In most land vehicles in use today, a drive train assembly is provided for transmitting rotational power from an engine/transmission assembly to one or more wheels of the vehicle. In a rear-wheel drive vehicle, a typical drive train assembly includes a tubular driveshaft which is connected between an output shaft of the transmission and an input shaft of a rear axle assembly to rotatably drive the rear wheels. In a front-wheel drive vehicle, a typical drive train assembly includes right and left halfshafts which are connected between a transaxle assembly and the right and left wheels, respectively.

In a four-wheel drive vehicle, a typical drive train assembly includes a transfer case which rotatably supports an input shaft for receiving rotational power from the engine/transmission assembly, as well as front and rear output shafts for transferring rotational power from the input shaft to the front and rear wheels of the vehicle, respectively. Typically, a front auxiliary driveshaft is connected between the front output shaft of the transfer case and an input shaft of a front axle assembly to rotatably drive the front wheels, and a rear driveshaft is connected between the rear output shaft of the transfer case and an input shaft of the rear axle assembly to rotatably drive the rear wheels. In some vehicles, the transfer case is spaced apart from the transmission, and a front driveshaft is connected between the output shaft of the transmission and the input shaft of the transfer case.

The different shafts are usually connected together by the use of universal joints. For example, a first universal joint is usually connected between the front

output shaft of the transfer case and a first end of the front auxiliary driveshaft, and a second universal joint is connected between a second end of the front auxiliary driveshaft and the input shaft of the front axle assembly. The universal joints provide a rotational driving connection from the front output shaft of the transfer case through the front auxiliary driveshaft to the input shaft of the front axle assembly, while accommodating a limited amount of angular misalignment between the rotational axes of these three shafts. The use of universal joints to connect both ends of a driveshaft increases the complexity and cost of the drive train assembly.

SUMMARY OF THE INVENTION

This invention relates to a vehicle drive train assembly which includes a source of rotational power and at least one rotatably driven vehicle wheel. A male splined member and a female splined member are connected between the source of rotational power and the vehicle wheel to transmit rotational power therebetween. At least one of the splined members is a driveshaft. The splines of the male splined member have side surfaces and outer surfaces which are convex in shape. The convex splines of the male splined member cooperate with the splines of the female splined member to connect the splined members together in a manner that allows for limited angular and axial movement therebetween. The angular movement is caused at least in part by up or down movement of the vehicle wheel during operation of the vehicle.

In another embodiment, the invention relates to a vehicle drive train assembly which includes a source of rotational power and at least one rotatably driven vehicle wheel. A male splined driveshaft and a female splined member are connected between the source of rotational power and the vehicle wheel to transmit rotational power therebetween. The driveshaft includes a main tubular portion, a male splined end portion, and a neck portion therebetween. The neck portion has a diameter which is less than the diameters of both the male splined end portion and the main tubular portion. The splines of the male splined member have side surfaces and outer surfaces which are convex in shape. The convex splines of the male splined member cooperate

with the splines of the female splined member to connect the splined members together in a manner that allows for limited angular and axial movement therebetween.

In a further embodiment, the invention relates to a vehicle drive train assembly which includes a source of rotational power and at least one rotatably driven vehicle wheel. A male splined member and a female splined member are connected between the source of rotational power and the vehicle wheel to transmit rotational power therebetween. At least one of the splined members is a driveshaft which is located completely outside of the source of rotational power. The splines of the male splined member have side surfaces and outer surfaces which are convex in shape. The convex splines of the male splined member cooperate with the splines of the female splined member to connect the splined members together in a manner that allows for limited angular and axial movement therebetween.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side elevational view, partly in cross-section, of a front auxiliary driveshaft connected between a front output shaft of a transfer case and an input shaft of a front axle assembly, the driveshaft including an end piece having convex splines in accordance with the invention.

Fig. 2 is an enlarged perspective view of the end piece of Fig. 1.

Fig. 3 is a top view of the end piece of Fig. 1.

Fig. 4 is a cross-sectional view of the end piece taken along line 4-4 of Fig. 3.

Fig. 5 is a cross-sectional view of a male splined end portion of the end piece taken along line 5-5 of Fig. 4.

Fig. 6 is a cross-sectional view of a convex spline of the end piece taken along line 6-6 of Fig. 5.

Fig. 7 is a cross-sectional view of a portion of the end piece of Fig. 4, showing a convex spline on the male splined end portion of the end piece.

Fig. 8 is a perspective view of the end piece of the driveshaft connected to the input shaft of the front axle assembly.

Fig. 9 is a cross-sectional view of the end piece of the driveshaft connected to the input shaft of the front axle assembly.

Fig. 9

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, there is illustrated in Fig. 1 several members of a vehicle drive train assembly, indicated generally at 10. The illustrated drive train members are part of the drive train assembly of a four-wheel drive vehicle. However, the invention can also be used on front-rear drive vehicles, rear wheel drive vehicles, or other types of vehicles in which a drive train assembly is provided for transmitting rotational power from a source of rotational power to at least one rotatably driven vehicle wheel.

In the embodiment shown, the drive train assembly includes a front auxiliary driveshaft 12. The driveshaft 12 typically includes a main tubular portion 14 which is in the shape of an elongated cylindrical tube having a generally continuous cross-section. The shape and size of the driveshaft 12 are typical of propeller shafts, although other shapes and sizes of driveshafts could also be used depending on the particular drive train assembly.

The driveshaft 12 is connected to an input shaft 16 of a front axle assembly 18. The front axle assembly 18 is conventional in the art. The driveshaft 12 is connected to the front axle assembly 18 by the use of a universal joint, indicated generally at 20. The universal joint 20 is conventional in the art and includes a yoke portion 22 of the driveshaft 12 which is attached to one end of the main tubular portion 14, such as by a weld. The universal joint 20 also includes a second yoke portion 24 which is attached to the input shaft 16 of the front axle assembly 18. A cross 26 is mounted between the two yoke portions 22 and 24. The universal joint 20 provides a rotational driving connection between the driveshaft 12 and the input shaft 16 of the front axle assembly 18 while accommodating a limited amount of angular misalignment between their rotational axes.

The driveshaft 12 is also connected to a front output shaft 28 of a transfer case 30. In a typical drive train assembly (not shown), a front auxiliary driveshaft would be

connected between a transfer case and a front axle assembly by the use of universal joints at both ends of the driveshaft. In contrast, the drive train assembly of this invention includes a connecting structure, indicated generally at 32, which is used in place of a universal joint at one end of the driveshaft 12. The connecting structure 32 includes a male splined member, the driveshaft 12 in the embodiment shown, and a female splined member, the front output shaft 28 of the transfer case 30 in the embodiment shown. Alternatively, the front output shaft 28 could be the male splined member while the driveshaft 12 is the female splined member. At least one of the splined members is a driveshaft which is usually located completely outside of the source of rotational power of the drive train assembly. In another alternate embodiment, the connecting structure 32 could be used to replace the universal joint 20 between the driveshaft 12 and the front axle assembly 18.

5 In the preferred embodiment shown in Fig. 1, the driveshaft 12 includes a male splined end portion 34, and a neck portion 36 between the male splined end portion 34 and the main tubular portion 14 of the driveshaft 12. The neck portion 36 has a diameter which is less than the diameters of both the male splined end portion 34 and the main tubular portion 14. As shown in Figs. 1-4, the preferred driveshaft 12 includes an end piece 38 which is attached to the main tubular portion 14 of the driveshaft 12. The end piece 38 includes the male splined end portion 34 and a tube seat portion 40 which is attached to the main tubular portion 14. The end piece 38 also includes the neck portion 36 which has a diameter less than the diameters of both the male splined end portion 34 and the tube seat portion 40. In the embodiment shown, the male splined end portion 34 has a diameter which is smaller than the diameter of the tube seat portion 40.

25 The end piece 38 can be attached to the main tubular portion 34 of the driveshaft 12 by any suitable method. For example, a conventional welding technique can be used to permanently join the driveshaft parts together. As is well known, conventional welding techniques involve the application of heat to localized areas of two metallic members, which results in a coalescence of the two metallic members. Such welding may or may not be performed with the application of pressure, and may

or may not include the use of a filler metal. Typically, if the end piece 38 is attached to the main tubular portion 34 by welding, the tube seat portion 40 has a diameter which is slightly more or less than the diameter of the main tubular portion 14, so that the end piece 38 and the main tubular portion 34 overlap in a tight fit.

5 In a preferred embodiment, the end piece 38 is attached to the main tubular portion 34 of the driveshaft 12 by a magnetically impelled arc butt (MIAB) welding method. In such a welding method, the tube seat portion 40 of the end piece 38 has the same diameter as the main tubular portion 14. The tube seat portion 40 and the main tubular portion 14 are forced together while applying a DC welding current. The
10 end piece 38 and the main tubular portion 14 are then moved apart to a distance of 1-3 millimeters in order to strike an arc. This arc is rotated at high speed around the circumference of the weld interface using a static radial magnetic field which can be generated using permanent magnets or electromagnets. Arc rotation is sustained for a few seconds until the ends of the tube seat portion 40 and the main tubular portion 14
15 are heated to a high temperature or are molten. The tube seat portion 40 and the main tubular portion 14 are then brought rapidly together under a predetermined pressure and the arc is extinguished. The molten metal at the weld interface is expelled and a solid phase weld results from sustained pressure, which consolidates the joint.

Any appropriate materials may be used for making the main tubular portion 14,
20 the yoke portion 22 and the end piece 38 of the driveshaft 12. The use of steel, aluminum, magnesium, and alloys of these materials, as well as composite materials, are all within the scope of the invention. In a preferred embodiment, the end piece 38 is made from a case hardened steel, preferably a high-strength grade of steel with a wear-resistant surface. The material could also be a lesser grade steel with a surface
25 treatment to strengthen the surface. In an alternate embodiment, the male splined end portion 34 of the driveshaft 12 is made from a material which is different from the material used to make the main tubular portion 14. The material used to make the male splined end portion 34 may be stronger and/or more wear-resistant than the main tubular portion 14 to better withstand the stresses at the splined connection. In one
30 such embodiment (not shown), the male splined end portion is formed as a ring having

splines on its outer circumferential surface, and the ring is attached to the main tubular portion by any suitable method, such as by welding.

As shown in Fig. 1, a seal 42 is provided to cover the connecting structure 32 between the driveshaft 12 and the front output shaft 28 of the transfer case 30, in order to prevent the entry of dirt, water and other contaminants into the connecting structure 32. The seal 42 also allows a limited amount of angular and axial movement between the driveshaft 12 and the front output shaft 28. Any suitable structure and attachment of the seal 42 can be used for this purpose. In the illustrated embodiment, the seal 42 is a flexible boot type seal which is attached at its ends with a pair of clamps 44 to the tube seat portion 40 of the end piece 38 and to the outer circumferential surface of the front output shaft 28.

As shown in Figs. 1-5, the male splined end portion 34 of the driveshaft 12 has a plurality of outwardly extending longitudinal splines 46 formed on its outer circumferential surface. The splines 46 each have a pair of side surfaces 48 on opposing sides of the spline 46, and a radially outer surface 50. In accordance with the invention, the side surfaces 48 and the outer surfaces 50 of the splines 46 are convex in shape. The convex shape of the splines 46 is best illustrated in Figs. 6 and 7. As shown in Fig. 6, the spline 46 has a pair of side surfaces 48 on opposing sides of the spline 46. The side surfaces 48 are both convex in shape. In the preferred embodiment, the side surfaces 48 are arcuate or crowned in shape, each forming a smoothly curving arc. As a result, the spline 46 is generally elliptical in shape. The arcuate side surfaces 48 each have a radius R1. As shown in Fig. 7, the spline 46 has a radially outer surface 50. The outer surface 50 is convex in shape. In the preferred embodiment, the outer surface 50 is arcuate or crowned in shape, forming a smoothly curving arc. The arcuate outer surface 50 has a radius R2. The convex splines 46 of the invention contrast with the straight splines used in a slip yoke assembly of a typical drive train assembly.

As shown in Figs. 1 and 8, the front output shaft 28 of the transfer case 30 has a plurality of inwardly extending splines 52 formed on its inner surface. The outwardly extending splines 46 of the driveshaft 12 cooperate with the inwardly extending

splines 52 of the front output shaft 28 to connect the driveshaft 12 to the front output shaft 28 in a manner that allows for limited axial movement therebetween. Moreover, the convex shape of the splines 46 of the driveshaft 12 allows for limited angular movement between the driveshaft 12 and the front output shaft 28. This feature of the invention allows the connecting structure 32 to be used in place of a universal joint in a vehicle drive train assembly. Small amounts of angular and axial movement between the driveshaft 12 and the front output shaft 28 often occur during operation of the vehicle. Such movements may be caused, for example, by up or down movements of the vehicle wheels and axles, a small amount of movement of the vehicle engine in its engine mount, and/or a small amount of frame twisting, which may all be caused by irregularities in the road surface or irregular vehicle operation. A slip yoke assembly of a typical drive train assembly does not allow angular movement between the connected drive train members.

Figs. 1, 8 and 9 illustrate the angular connection between the end piece 38 of the driveshaft 12 and the front output shaft 28 of the transfer case 30, allowed by the convex splines 46 of the invention. As shown in Fig. 9, the end piece 38 and the front output shaft 28 are connected at a joint angle A (the angle between the longitudinal axis L1 of the end piece 38 and the longitudinal axis L2 of the front output shaft 28). Preferably, the convex splines 46 are shaped to allow a joint angle of at least about 3°, more preferably at least about 5°, and typically between about 3° and about 7°. It has been determined that the radius R1 (Fig. 6) of each of the convex side surfaces 48 of the spline 46 is the most important structural feature for allowing a desired joint angle. In general, the smaller the radius R1, the larger can be the joint angle. The optimum radius R1 will differ depending on the particular drive train assembly. The radius R2 (Fig. 7) of the convex outer surface 50 of the spline 46 also affects the amount of joint angle allowed. In general, the smaller the radius R2, the larger can be the joint angle. The optimum radius R2 will differ depending on the particular drive train assembly.

In the embodiment shown in Figs. 8 and 9, the reduced diameter neck portion 36 of the end piece 38 is also important for allowing the angular connection between the end piece 38 of the driveshaft 12 and the front output shaft 28 of the transfer case

30. The neck portion 36 provides clearance for the end of the output shaft 28 to extend inwardly toward the side of the end piece 38 when the two members are angled relative to each other. However, in some embodiments of the invention, a sufficient angular connection can be achieved without the use of a reduced diameter neck portion 36. For example, the male splined end portion 34 of the end piece 38 could be formed with a larger diameter, and/or the male splined end portion 34 could be connected closer to the outer end of the front output shaft 28.

Any suitable method can be used to manufacture the end piece 38 including the male splined end portion 34 having the convex splines 46, the neck portion 36 and the tube seat portion 40. Preferably, the end piece 38 is manufactured using a forming operation, such as a forging operation or a rolling operation. In one embodiment, a hot metal blank is forged into the rough shape of the end piece 38. A recess having a hexagonal outer portion and a conical inner portion is formed in one end of the blank, and a conical recess is formed in the other end of the blank. Figs. 2 and 4 show a hexagonal recess 54 and a conical recess 56 formed in the opposing ends of the end piece 38. The formed piece is mounted on a lathe; the recesses 54 and 56 enable the lathe to hold and center the formed piece. The lathe has a rotatable drive member having a hexagonal end portion, which extends into the hexagonal recess 54 to drive the formed piece to rotate. The lathe machines the outer surface of the formed piece to produce its final shape except for the convex splines. In production, an automated turning center would typically be used for machining instead of a lathe. Alternatively, a net forming process could be used instead of the forging process followed by the machining process. After the machining operation, the convex splines 46 are created by a machining process which uses a suitable tool, such as a gear hobbing, to cut the splines into the desired shape. Alternatively, the splines could be created by a forming operation such as roll forming.

In accordance with the provisions of the patent statutes, the principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced

otherwise than as specifically explained and illustrated without departing from its spirit or scope.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217
2218
2219
2220
2221
2222
2223
2224
2225
2226
2227
2228
2229
2230
2231
2232
2233
2234
2235
2236
2237
2238
2239
2240
2241
2242